CHAPTER 4

SYSTEM DESCRIPTION AND METHOLOGY

4.1 Photovoltaic water pumping station at Nong Sanuan Village

Nong Sanuan Village is in Phichit Province. The pumping station is installed at a distance of several hundred meters to the village center. The pump delivers water from an artificial pond of approximately 70m x 70m size; the water level varies seasonally between approximately 1m and 3.5m. The use of ground water from wells is, according to information from the Civil Works department, often not possible because of the high salt content of water.

The pond water is used in the village for household applications such as washing and cleaning or plant irrigation. It is not foreseen as drinking water, as no water purification is applied.

The pumping station consists of conventional commercially available components: the DC current of the photovoltaic array is inverted into AC current (three-phase) by the inverter. The electronic control of the inverter operates the asynchronous motor of the pump through frequency - and voltage variation. The PV array is operated close to the maximum power point (MPP). The 7-stage centrifugal pump is joined together with the motor as a sealed, submerged unit. It is fixed in the pond by means of a steel support frame.

The pumping station went into operation in 1994. The system was designed to deliver an average water amount of 20m^3/day for approximately 50 of the 200 inhabitants of Nong Sanuan Village.

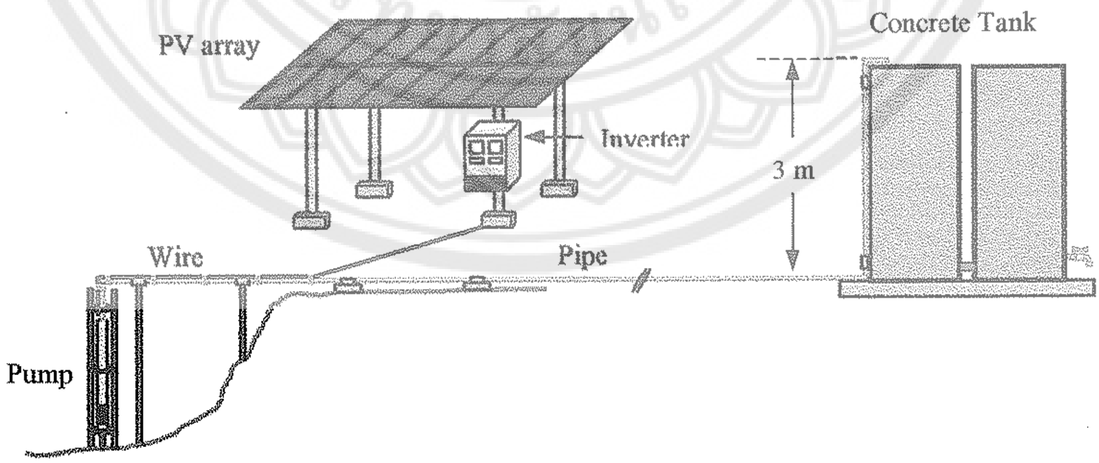
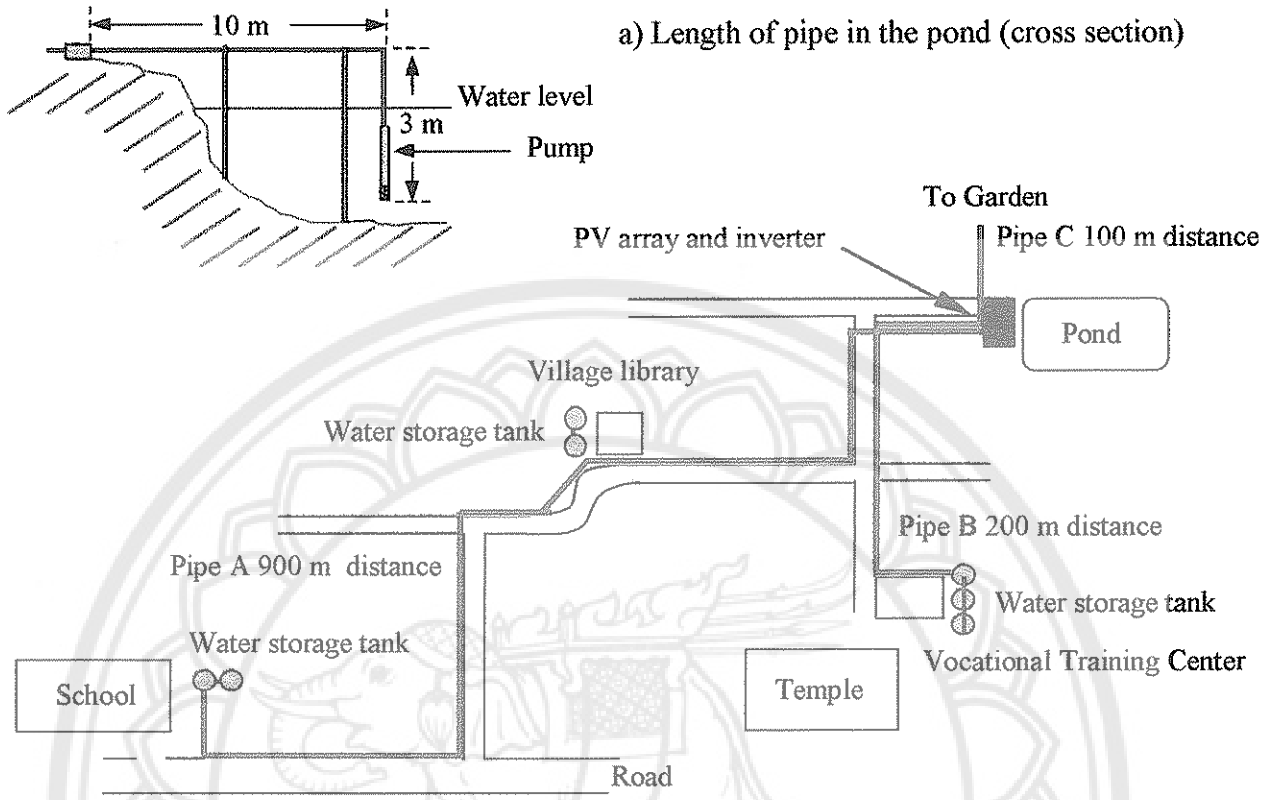


Figure 3 Schematic illustration of the PV water pumping system.



a) Length of pipe in the pond (cross section)

b) Length of pipes in the village (top view)

Figure 4 The pipeline diagram of the system at Nong Sanuan village.

4.2 The technical information and characteristic of instruments

4.2.1 PV pumping system

Table 2 General information of PV pumping at Nong Sanuan village.

Location	Nong Sanuan village, Tambon Huay Ruam, Bangmulnak distric, Phitchit
Latitude	16° 48' N
Longitude	100° 32' E
Topology	Low-lying
Water using goal	Consumption
No. of people in village	200 person (approx.)
No. of people using station	50 person (approx.)
Pond size	approx. 70m x 70m
Level of water	Between approximately 1m and 3.5m.
Year installation	1994
Design and Installation	by the Dept. of Civil Work

4.2.2 PV generator

Table 3 PV characteristic of PV pumping at Nong Sanuan village.

Type of modules	BP TS 1255 HP, mono-Si cells
Amount	16 modules
Rated PV module power	55 Wp
Rated power PV generator	880 Wp
Configuration	8 modules in series, 2 modules in parallel
Orientation	south, 15° inclined
Peak power voltage	17.5 V
Peak power current	3.2 A
Open circuit voltage	21.85 V
Short circuit current	3.37 A
Length	825 mm.
Width	530 mm.
Thickness	43.5 mm.

4.2.2 Inverter

Table 4 Inverter characteristic of PV pumping at Nong Sanuan village.

Type	Grundfos SA 1500
Rated inverter power	1500 W_{DC}
Maximum power	1960 W
Rated operation voltage	120 V_{DC}
Load voltage range	100 – 140 V_{DC}
No load voltage at nominal voltage	155 V_{DC}
No load voltage at maximum voltage	175 V_{DC}
Nominal load current	12.5 A
Maximum load current	14.0 A
Nominal battery operation	120 V_{DC}
Range of battery operation	100 – 140 V_{DC}
Maximum output current	14.0 A
Output frequency	63 Hz
Rated efficiency	96%
Casing	Black-anodized aluminum
Enclosure class	IP 54
Weight	4.4 kg.
Dimension	217 x 150 x 275 mm.
Ambient temperature	-10 °C to + 60 °C
Storage temperature	-25 °C to + 85 °C
Relative humidity	Maximum 100 %

4.2.3 Motor/pump unit

Table 5 Motor/pump characteristic of PV pumping at Nong Sanuan village.

Type	**Grundfos SP 5A-7 7-step centrifugal pump**
Rated power consumption (50 Hz)	550 W , 0.75 HP
Maximum power raying	1200 W
Nominal voltage input	195 V
Rated operation voltage (50 Hz)	3 x 65 V
Rated current (50 Hz)	8.8 A
cos φ (50 Hz)	0.87

4.2.4 Water storage

Table 6 Tank characteristic of PV pumping at Nong Sanuan village.

Type	Concrete
Rated capacity	20 m^3
Height	3 m.

4.3 Data collection

All data were collected by a MODAS 1632 Data logger. Data was collected every 10-minutes. This study ignored some non-essential parameters and some periods of data to make analysis easier. Data for each day was used which started at 8.00 am and finished at 5.00 pm. The diagram of the measuring installation was as follows.

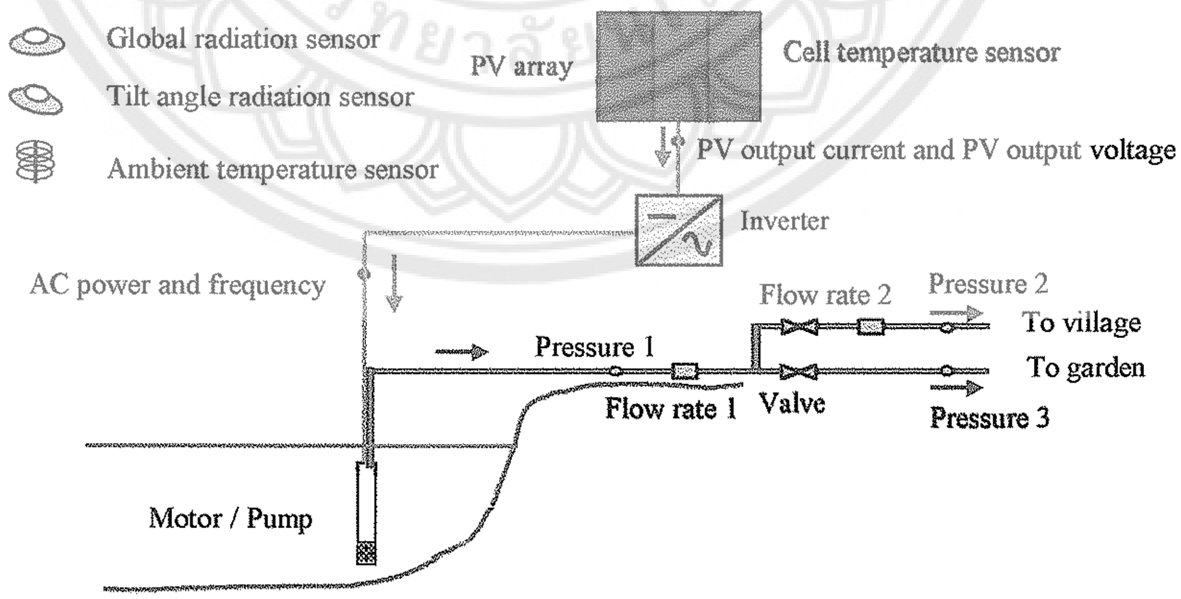


Figure 5 Measuring diagram of PV water pumping system at Nong Sanuan village.

4.4 Measuring Instrument

Table 7 Measuring information of PV pumping at Nong Sanuan village.

Parameter	Symbol	Instrument	unit
Global radiation	G_T	Pyranometer	W/m^2
Tilt radiation	G_{Tilt}	Pyranometer	W/m^2
Ambient temperature	T_A	Thermocouple Type K	° C
Cell temperature	T_C	Thermocouple Type K	° C
PV output voltage	V_{PV}	Modas data logger	V
PV output current	I_{PV}	Modas data logger	A
AC power from inverter	P_{AC}	Wattmeter	W
Suction pressure	P_S	Pressure gauge	barr
Pipe water pressure	P_W	Pressure gauge	barr
Inverter frequency	F	Modas data logger	Hz
Flow rate	Q	Flowmeter	m^3

4.5 Data analysis

This report divides the time range into three parts which are:

- short term that will use data only each month
- middle term that will use data for about four months or a season
    - Winter (November – February)
    - Summer (March – June)
    - Rainy (July – October)
- long term that will use data for all year (October 1997 – September 1998)

All collected data were used to find the efficiency of system, the performance and evaluation of system and to find the fit prediction by the simulation equation method. The efficiency of the system was found by formulas in chapter 3.

4.5.1 Short term analysis

The objectives of short-term analysis were to find the efficiency of the system and of each part including the PV array, inverter system and motor/pump for each month. And use the relation of each parameter plot the graph. From the related graph, the simulation equation was found using the Excel program.

4.5.2 Middle term analysis

The objectives of middle term or season analysis were to find the efficiency of the system for the four months of each season:.

- Winter (November – February)
- Summer (March – June)
- Rainy (July – October)

In each season we can find the efficiency of the system and each component including the PV array, inverter system and the motor/pump. And using the relationships of each parameter, we can plot the graph to determine the overall relationships. From the related graph, we can find the simulation equation by the Excel program. Using the simulation equation we can improve the system and predict the operation of system in difference conditions.

4.5.3 Long term analysis

For long term or yearly analysis we can find the efficiency of the system and of each component such as the PV array, the inverter system and the motor/pump by formulas in chapter 3. And, using the formulas in chapter 3 we can find the reference yield, performance ratio and final yield of the system. Using the values of each parameter we can plot a graph to consider the relation between each parameter. From the related graph, we can find the simulation equation by the Excel program. We can then use the simulation equation to improve the system and predict operation of the system in different conditions.

4.6 System simulation

The simulation is used for predicting the system operation with testing by real operation. A good simulation uses real operational condition analysis with the system working under difference condition. In this report is developed the simulation for the continuous operation of the pumping system from 3 October 1997 to 30 September 1998.

4.6.1 PV simulation

The PV system can be simulated by the use of output and input parameters that affect the PV system. An important output parameter of the PV system is the power that is the product of output current and voltage. And, both current and voltage are effected by insolation and cell temperature following the theory of solar cells. So, we can write the relationship of these parameters in a function form like this.

$$P = f(I_{PV}, V_{PV}) \qquad ....(4.1)$$

And,

$$I_{PV} = f(G_{Tilt}, T_C) \quad , \quad V_{PV} = f(G_{Tilt}, T_C) \qquad ....(4.2)$$

So, we can simplify this form to.

$$P_{PV} = f(G_{Tilt}, T_C) \qquad ....(4.3)$$

4.6.2 Motor and Pump simulation

In the same way, the motor and pump system can be simulated by using output and input parameters that effect the PV system. The efficiency of the motor/pump system depends upon the flow rate and AC input power. So, we can write the relation of these parameters in a function form like this.

$$H_T = f(P_{AC}, Q) \quad \text{..........(4.4)}$$

Thus the total head or H_{total} is a function of AC power that is input to the motor/pump and of the flow rate.

4.6.3 Pipe simulation

In the pipe system there are two sections that combine to produce the total head. First is the static head that is constant value determined by the physical conditions of the system. And, the other is friction loss or head loss in pipes that depends upon the flow rate. So, the efficiency of the pipe system is dependent upon the flow rate of the system. We can write the relationships into a function form like this.

$$H_T = f(Q) \quad \text{..........(4.5)}$$

4.6.4 System simulation

For whole system, the main output that was needed in the pumping system is the water volume flows. And, it was the tilt radiation that was the primary input power. So, we can write the relationships of the pumping system into the function like this.

$$Q = f(G_{Tilt}) \quad \text{..........(4.6)}$$